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Activation of intentional mechanisms through utilization of nonsymbolic movements in aphasia rehabilitation

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Abstract—Intentional mechanisms play an important role in complex self-initiated actions, such as language and gesturing. Deficits demonstrated in nonfluent aphasia may be a result of a disconnection between or damage to the initiation (intention) and production mechanisms in the left hemisphere. In chronic nonfluent aphasias, damaged language production mechanisms in the left hemisphere may switch to homologous regions in the right hemisphere while the initiation mechanisms remain active in the left hemisphere. A treatment was developed to prime right-hemisphere initiation mechanisms with movements of the nondominant hand, thereby bringing initiation into the right hemisphere where the language production mechanisms have been shifted. Three subjects with stable, chronic nonfluent aphasias were trained in daily sessions with a therapist to perform a complex nonsymbolic movement sequence with their nondominant hand to initiate naming trials of simple line drawings. Naming probes were administered during pretreatment baseline sessions and before each treatment session. All three subjects demonstrated a stable baseline and a significant increase over baseline performance in the percentage correct on naming probes during the treatment. Findings indicate that more extensive investigations of this newly developed treatment are justified and suggest that activation of right-hemisphere initiation mechanisms may enhance word production accuracy in stable, chronic nonfluent aphasias.

Key words: *aphasia, initiation, intention, rehabilitation.*

INTRODUCTION

Language comprehension and output require the successful integration of multiple brain functions, including intention. Intention, defined as preparation to respond, is particularly important in controlled complex behaviors, such as word generation and deliberate complex movements. In their review of functional neuroimaging literature, Picard and Strick have demonstrated involvement of the presupplementary motor area (pre-SMA) in initiation of complex language behaviors, including word generation [1]. Involvement of pre-SMA in initiation of language partially explains why lesions to this area produce a form of nonfluent aphasia with poor word generation but relatively good comprehension and repetition [2]. The initiation or generation problems demonstrated in

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nonfluent aphasia may be due to a disconnection between or damage to the medial frontal intentional and lateral frontal language production mechanisms of the left hemisphere. In addition, a mismatch between the hemisphere performing language production processes and the hemisphere initiating language functions may exacerbate initiation problems in language.

Following an infarction in the anterior portion of the dominant middle cerebral artery territory, one patient with nonfluent aphasia underwent functional magnetic resonance imaging (fMRI) in our laboratory during a word production task. Findings indicated a shift to right-hemisphere lateral frontal production mechanisms while medial frontal intentional mechanisms remained active in the left hemisphere [3]. Given these findings, it was hypothesized that it would be possible to prime, or activate, right-hemisphere initiation mechanisms with the use of a complex movement sequence of the left hand. The pairing of American Indian Sign Language performed with the left hand and oral production of words during object naming has demonstrated success in aphasia rehabilitation [4–7]. In these treatments, symbolic gestures representing an object and the verbal label are performed simultaneously, with therapeutic improvement demonstrated only when the gesture and oral word production are paired together, not when either is performed alone. We considered that the facilitation in naming demonstrated in these studies may be more related to activation of right-hemisphere intentional mechanisms during performance of a complex movement sequence with the left hand than to the pairing of the symbolic component of the gesture with word production.

Activation of intentional mechanisms in pre-SMA has been demonstrated in studies where subjects are asked to complete a complex movement that involves motor programming selection, such as moving a joystick in a particular direction [1]. In contrast, when subjects are asked to perform simple movements, such as moving a joystick in the same direction repeatedly, activation of the SMA is demonstrated [1]. Based on the information linking pre-SMA activation with higher order motor control, performance of a complex movement sequence with the left hand likely primes right-hemisphere mechanisms that also can initiate language production. Although previous studies have not addressed the role of intentional mechanisms in aphasia rehabilitation directly, we suggest that this may be the active component leading to improvements demonstrated in the pairing of sign language and oral naming. If this hypothesis is correct, then nonfluent aphasic patients trained to pair a left-handed nonsymbolic movement sequence with naming of objects will increase their naming accuracy.

Based on these premises, a novel treatment designed to facilitate naming in chronic nonfluent aphasic patients was developed for this study. Believing that mismatches between hemispheres regarding language initiation and production may be common, we hypothesized that initiation of action with the nondominant hand with the use of a nonsymbolic movement sequence would engage right-hemisphere intentional mechanisms. These mechanisms would include those relevant to initiation of language production processes. Priming of these mechanisms before naming may facilitate language initiation and production by switching language initiation mechanisms into the same hemisphere as production mechanisms. More specifically, this study proposed to increase naming accuracy in patients with nonfluent aphasia by initiating naming trials with nonsymbolic gestures of the nondominant hand. The experimental hypothesis stated that patients would show improved naming of probe stimuli during this treatment as opposed to naming the same stimuli during an untreated baseline.

METHOD

Participants

Three patients (described later in this paper) participated in this study. All participants had left-hemisphere damage resulting from stroke, as determined by medical records. To better control for the effects of spontaneous recovery, we ensured all subjects were at least 6 months poststroke. Before enrolling in the study, all subjects had undergone extensive speech therapy with limited improvements. Inclusion criteria included subjects who had to have a raw score of less than 46 on the Boston Naming Test, have left-hemisphere damage, be right-handed, and be native English speakers who could follow simple verbal instructions. Exclusion criteria included significant head injury (loss of consciousness > 6 hours) or any brain disease such as probable Alzheimer's Disease, right-hemisphere damage, inability to determine if language was fluent or nonfluent in the acute stages of recovery, history of drug or alcohol abuse, diagnosis of a major psychiatric disorder, learning disabilities, language delays, or attention deficit disorder. Informed consent was obtained for all subjects in accordance with a protocol approved by the Health Science Center Institutional Review Board at the University of Florida.

Subject J.S. was a 44-year-old male who sustained an ischemic stroke in the left middle cerebral artery territory, involving the left sensory-motor cortex and pars opercularis 2 years before enrolling in the study. He had received extensive speech and language therapy but had discontinued therapy 4 months before enrolling in this study. Immediately poststroke, he was nonverbal, but progressed to a level where his speech was telegraphic, with utterances of one to three words in length, secondary to word-finding difficulties. In addition, J.S. displayed severe apraxia of speech, which was characterized by numerous phonemic distortions, substitutions, blend reductions, and syllable deletions. He was unable to phonologically sequence multisyllabic words. J.S. received a score of 37 on the Boston Naming Test, which was administered before initiation of treatment [8]. Performance on this test revealed that he was aided by phonemic cues and produced several semantic paraphasias. The majority of errors demonstrated during treatment were missed phonological targets versus naming of the correct lexical item. These responses were judged to be unintelligible if the referent was not known.

Subject C.W. was a 71-year-old male who sustained a left middle cerebral artery stroke 2 1/2 years before enrolling in the study. Poststroke, he was nonverbal and had a vocabulary of less than 20 words. However, at the time of treatment, he was able to answer simple questions, use everyday expressions, give familiar names, and make simple requests. He had significant difficulties in answering questions that were more complex and responded with “I don’t know” to most questions. C.W.’s comprehension remained intact, and he was able to communicate very effectively through writing. Before treatment onset, C.W. received a score of 15 on the Boston Naming Test [8]. His errors in treatment were primarily semantic substitutions or “I don’t know” responses.

Subject R.B. was a 45-year-old male who sustained a left middle artery stroke 2 years before enrolling in the study. Immediately poststroke, he was nonverbal, but he progressed to a level where he was able to produce 5- to 10-word simple sentences. His speech was slow, with long pauses, and his comprehension remained intact. Results from pretreatment testing on the Boston Naming Test [8], on which he scored 32, primarily were due to phonemic distortions. Phonemic cueing did help R.B find the target word, but he continued to demonstrate phonemic errors. The errors made in treatment primarily were due to semantic substitutions or the inability to name within the time limit.

Design

We used the single subject A-B design for this study. In the A-B design of this experiment, each subject underwent a baseline (A) phase followed by three phases of treatment (B). In this design, the baseline (A) phase was conducted through repeated sessions in which the subject received the measurement probe and no treatment. Once stability had been established, the treatment (B) phase was initiated. We then made comparisons between accuracy of naming probe stimuli in the treatment phase and baseline phase, and inferences were drawn from the differences between the phases.

Procedure

During the pretreatment baseline, each subject performed a naming task each day for a total of nine sessions (eight for subject R.B. because of a missing data point) to establish a baseline rate of percent correct of naming accuracy and reaction time. A computer monitor was placed directly in front of the subject. Each naming probe set contained 40 black and white line drawings, approximately 4 in. × 4 in. The 40 pictures in the probe set (**Figure 1**) consisted of 10 pictures from each treatment phase (the trained pictures), for a total of 30 pictures, and 10 pictures that were not trained in any of the treatment phases (the untrained pictures).

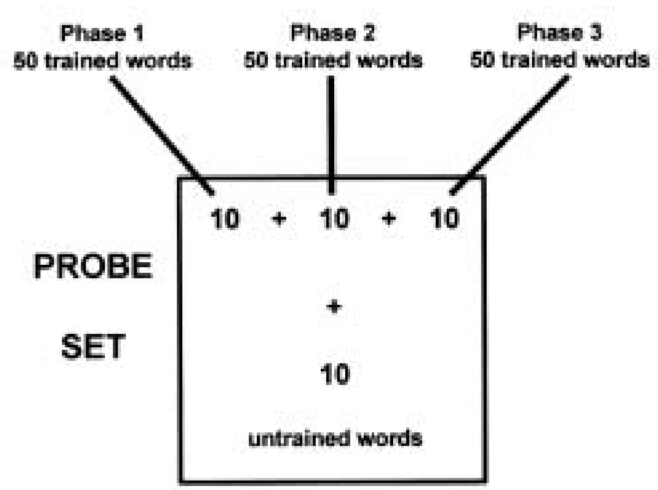

Figure 1.
Composition of probe set administered to measure treatment progress.

Each probe set contained 12 high-frequency (21 to 717 occurrences per million), 12 medium-frequency (4 to 20 occurrences per million), and 16 low-frequency words (0 to 3 occurrences per million), paralleling the frequency distribution of the words in the treatment sets [9]. Because R.B.'s accuracy averaged 92.68 percent on this probe set, a different probe set consisting of 40 low-frequency words was established for him to avoid a ceiling effect.

After this baseline period, we initiated the experimental treatment. The treatment consisted of three phases, and each phase consisted of 10 sessions. One complete treatment session included the presenting and naming of a set of 50 black and white line drawings. One set of words was trained during each phase of treatment, for a total of three sets of 50 words. Each set contained 15 high-frequency (21 to 717 occurrences per million), 15 medium-frequency (4 to 20 occurrences per million), and 20 low-frequency (0 to 3 occurrences per million) words to prevent subjects from achieving ceiling effects on the naming tasks. We assigned frequency categories based on Francis and Kucera's "Frequency Analysis of the English Language" [9]. Each set contained pictures of 9 living objects and 31 nonliving objects. Each treatment session lasted approximately 45 minutes. During the naming-probe tasks, the therapist began each trial by pressing the mouse button, which initiated a timer. A black and white line drawing appeared in the center of the screen, and the subject named the picture as quickly as possible. The subject was not given any instruction as to whether he should or should not use the movement sequence learned in treatment to facilitate their naming. The therapist recorded correct and incorrect responses by pressing either the left or right mouse button. If the subject was unable to name the picture within 20 seconds, the program recorded an incorrect response and automatically advanced to the next probe item. Reaction time for both correct and incorrect responses was recorded. The therapist did not provide feedback about the accuracy of naming during probe trials.

Intention Treatment

The three phases of the treatment are described in the subsequent paragraphs. All phases are designed to activate intention mechanisms in the right hemisphere through complex movements generated by the left hand. The staging of treatment in successive phases was designed to progress from a movement that used an external apparatus and was prompted with external cues (tone and flashing star) to a complex movement. This movement required the patient to initiate a movement sequence without an external apparatus or cues. The final movement sequence (a meaningless circular gesture) was both internally generated and generalizable to situations outside of the treatment session. This movement sequence was unrelated to any word and therefore nonsymbolic in nature. The circular gesture was the same for every word and did not resemble any symbolic action with which the patient was already familiar.

Phase 1

The subject was seated at a desk with body and head facing straight ahead. The computer monitor was situated directly in front of the subject. The therapist began the trial by pressing the mouse button. Then, a star approximately 1 in. × 1 in. appeared at the center of the screen and a 1,000-Hz tone was sounded. The star varied in color and orientation from trial to trial. To initiate the presentation of the line drawing, the subject lifted, with the left hand, a lid on a small box located to his left, and pressed a button located within the box. After the button was pressed, the tone and star were eliminated, and after a 2-second delay, a black and white line drawing appeared in the center of the screen and a timer was started. If the subject correctly named the picture, the therapist ended the trial by pressing the mouse button, which stopped the timer and removed the drawing from the screen. If the subject incorrectly named the picture, the therapist named the picture while making a meaningless circular gesture with the left hand. The subject repeated the correct picture name aloud while making this gesture. The subject was trained on the same set of 50 line drawings each day of this treatment phase.

Phase 2

The subject was positioned the same as in phase one. The therapist began the trial by pressing a mouse button and a star appeared at the center of the screen (the tone was eliminated in this phase). The patient again lifted the lid on a small box and pressed a button with the left hand to remove the star from the screen. After a 2-second delay, a drawing appeared in the center of the screen, which the subject attempted to name. Incorrect responses were corrected, as in phase 1. The subject was trained on a different set of 50 line drawings from those used in phase 1.

Phase 3

The subject was positioned the same as in the previous two phases. The therapist began the trial by pressing a mouse button, upon which a star appeared in the center of the screen. The subject performed a meaningless circular gesture with the left hand. The therapist pressed the mouse button to initiate the presentation of the pictures once the subject repeated this gesture three times. Response instructions and correction of incorrect responses remained the same as in the previous two phases. The subject was trained on a different set of 50 line drawings for this phase than for the previous two phases.

Two tasks, the copy of the Rey-Osterrieth Complex Figure Test and the Wechsler Adult Intelligence Scale-Revised Edition (WAIS-R), Block Design subtest, were administered before each phase of treatment and following treatment completion [10,11]. We hypothesized that scores on these measures would remain consistent over the four administrations, based on the assumption that this experimental treatment selectively improves language functions and does not lead to changes in general cognitive functions. Only the copy portion of the Rey-Osterrieth, and not the immediate and delayed memory portions, was administered. Our intent was to assess visuospatial processing functions located in both the left and right frontal regions, rather than functions located in posterior memory areas. To further assess frontal constructional abilities, we administered four different block design sets. The original WAIS-R set and three alternative design sets, equated for complexity on each trial, were administered in random order to each subject to decrease the influence of practice effects [12]. The experimental treatment is designed to selectively improve language functions; therefore, measures on tasks that target visuospatial processing and constructional abilities are not expected to improve during treatment. The choice of these two tasks as control measures was based on observations that tapped both frontal and parietal functions in both the left and right hemispheres. Lezak noted that the copy of the Rey-Osterrieth Figure measures both frontal and parietal functions, as demonstrated by the different error patterns of patients with lesions in the two regions [13]. In addition, Lezak notes involvement of both left and right hemispheres in these tasks. The Rey-Osterrieth and Block Design were chosen over other more traditionally "frontal" tasks because of their relative lack of involvement in verbal functions (aside from using verbal skills to understand the instructions) and their repeatability. We hypothesized that subjects would not improve on these measures, thereby indicating that any improvements in naming during treatment were language-specific and not a result of a generalized cognitive improvement.

RESULTS

Each subject completed a naming probe task to establish performance during 8 sessions of pretreatment baseline and before each of the 30 treatment sessions. Each treatment session began with the probe, followed by the experimental treatment. Because the probe task was administered before the first session of treatment, the probe constituted a ninth baseline measurement. Likewise, the probe task given in the session during which a new phase was initiated was considered a measure of effectiveness for the previous phase because the probe preceded initiation of the new phase. The total number of pictures correctly named in the verbal probe was calculated and a percentage correct score was obtained for each day. The subject was allowed 20 seconds to generate a response, and if they were unable to do so within this time limit, the response was recorded as incorrect. For all subjects, this was an extremely rare event and minimally influenced the total percentage of correct responses. The number of trained and untrained pictures named correctly was also calculated for each day. Results are presented in **Table 1**.

To determine the stability of baseline performance, we analyzed the total percentage of correct responses for the nine baseline sessions with the C statistic [14]. The

Table 1.
Summary data: Average percentage of correctly named pictures.

	J.S.			C.W.			R.B.		
Phase	Total	Trained	Untrained	Total	Trained	Untrained	Total	Trained	Untrained
Baseline	43.78	—	—	39.72	—	—	68.75	—	—
1	55.75	62.00	53.64	46.50	56.37	42.75	79.44	78.63	79.83
2	70.75	72.87	68.44	58.00	63.00	53.00	91.39	91.43	92.63
3	78.06	81.11	68.89	63.89	62.96	66.67	95.63	94.82	97.78

C statistic was also used to determine if the slope of the treatment phases was significantly different from that of the baseline. The C statistic is designed to reach significance if the data have an upward trend, based on the assumption that both the mean and the variance will increase when there is a trend. In addition, the C statistic will become larger if the difference from the mean increases more rapidly than the difference from the successive data point changes [14]. This statistic was used for several reasons. First, it provided a method to determine the stability of the baseline. Once a stable baseline was established, any improvements demonstrated following the initiation of treatment could more confidently be attributed to treatment effects. Stability in the baseline also suggests that repeated exposure without treatment, or practice, does not result in improvement. Second, time series analysis, an alternative method for analysis of treatment data for single subjects, requires at least 50 to 100 data points per treatment phase, while the C statistic only requires 8 data points per phase. Third, the C statistic offered support to changes that are seen with visual analysis, the traditional method for analysis in single subject designs.

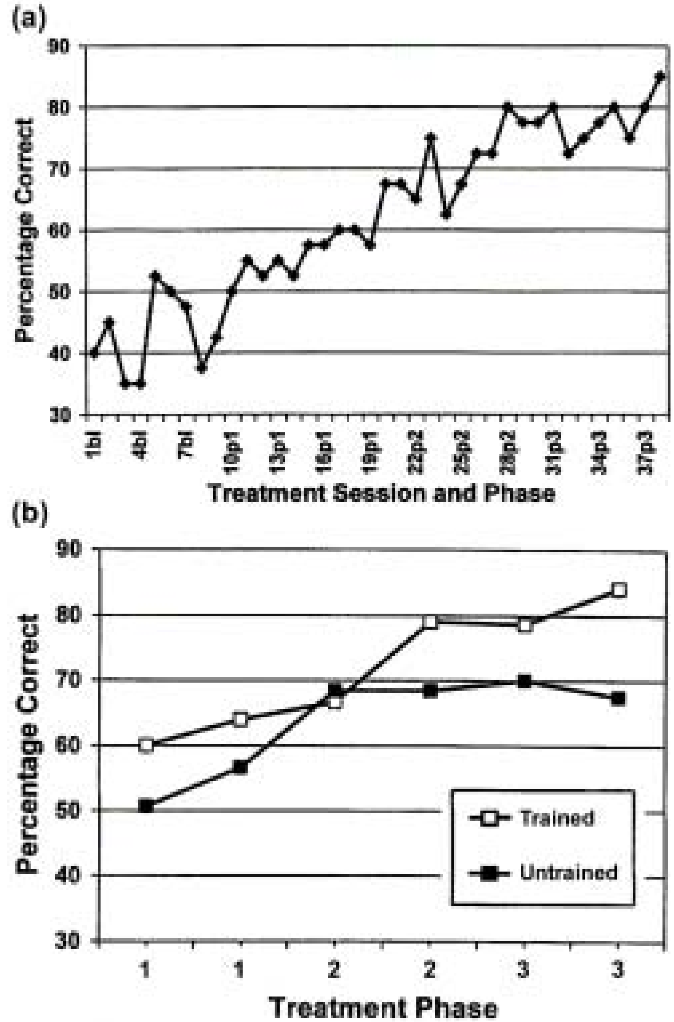

Figure 2.
Subject J.S.: **(a)** Percent correct for all probe trials in baseline and treatment sessions. First nine sessions were baseline sessions, followed by 10 phase 1 treatment sessions, 10 phase 2 treatment sessions, and 9 phase 3 treatment sessions. (In ninth session, probe set was administered before initial treatment. Thus, probe on ninth day was counted as a part of baseline, since no treatment had occurred before probe was administered.) bl = baseline, p1 = phase 1, p2 = phase 2, p3 = phase 3. **(b)** Percent correct for trained and untrained items in probe set. Percent correct was averaged across first and second halves of each treatment phase.

Subject J.S.

A stable pretreatment baseline was obtained for accuracy of the naming probe ($C = 0.14$, $Z = 0.47$, $p > 0.05$), and his average percentage correct was 43.78. His average score improved to 78.06 percent correct for phase 3 (**Table 1**). The slope of the total percent correct from the three treatment phases was significantly different from the baseline slope ($C = 0.91$, $Z = 5.79$, $p < 0.05$) (**Figure 2(a)**). The average percent correct for trained and untrained words also increased as J.S. progressed through treatment phases (**Figure 2(b)**); performance generally was better for the trained than the untrained stimuli.

J.S. learned the gesture with ease and consistently used it to aid picture naming in the probe set beginning in phase 2. The gesture appeared to decrease the amount of groping and to aid motor planning while he generated the target word. J.S. was tested again 3 months after termination of treatment, and he accurately named 82.5 percent of the pictures, indicating that he continued to demonstrate treatment gains. Rehabilitation staff who have known J.S. for some time but have not been involved in his treatment have noted significant improvements in functional communication since the beginning of the experimental treatments. In addition, J.S. continued to use the gesture in everyday settings.

Subject C.W.

A stable pretreatment baseline was obtained for accuracy of the naming probe ($C = –0.29$, $Z = –0.98$, $p > 0.05$). While one can see some increase in performance from the first to last baseline sessions, there is clearly no improvement across the last five baseline sessions, which is the reason the C statistic indicates no improvement during the baseline phase. His average percent correct was 39.72 at baseline, with an improvement to 63.89 percent correct, the average for phase 3 (**Table 1**). The slope of the total percent of correctly named pictures from the treatment phases was significantly different from the slope of the baseline ($C = 0.66$, $Z = 4.12$, $p < 0.05$) (**Figure 3(a)**). His naming accuracy improved for both the trained and untrained pictures (**Figure 3(b)**). Until the third phase of treatment, performance on the trained pictures was consistently better than performance on the untrained pictures.

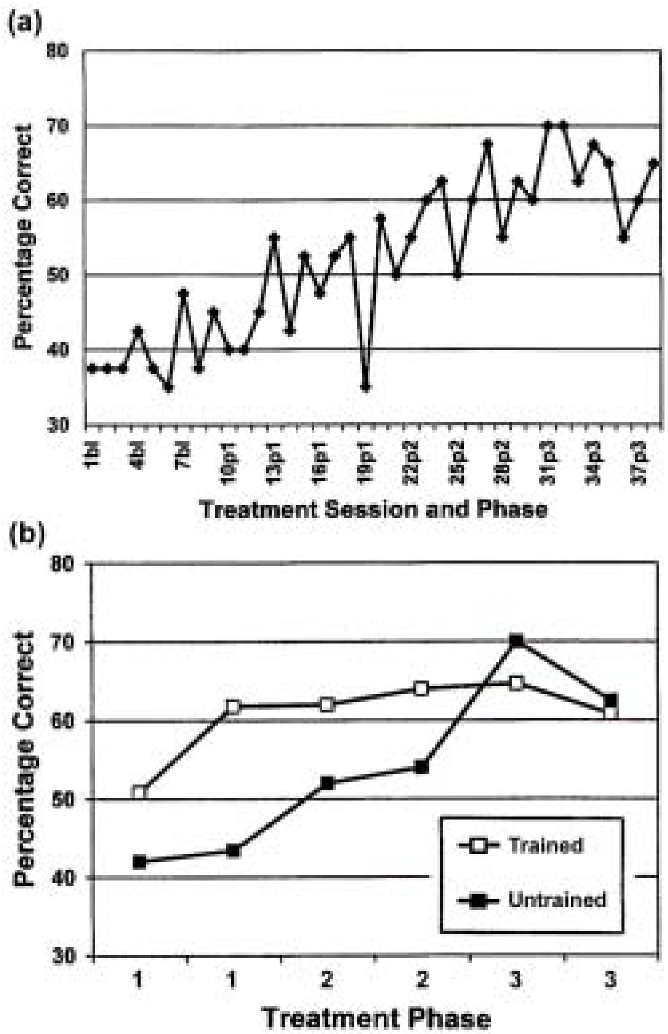

Figure 3.
Subject C.W.: **(a)** Percent correct for all probe trials in baseline and treatment sessions. First nine sessions were baseline sessions, followed by 10 phase 1 treatment sessions, 10 phase two treatment sessions, and nine phase 3 treatment sessions. bl = baseline, p1 = phase 1, p2 = phase 2, p3 = phase 3. **(b)** Percent correct for trained and untrained items in probe set. Percent correct was averaged across first and second halves of each treatment phase.

C.W. inconsistently used the gesture while naming pictures, with demonstration of this phenomenon beginning in the probe set following the second phase of treatment. As he progressed through treatment, his "I don't know" responses decreased and his word retrieval skills improved. When C.W. was tested 6 months after termination of treatment on a naming probe similar to the one administered during treatment, he accurately named 42.50 percent of the pictures. This is a considerable decrease in naming accuracy, because his percentage correct at this time was near baseline levels. C.W.'s use of the gesture was limited to the treatment setting, which may explain why naming accuracy during follow-up was near baseline levels. Anecdotally, it appeared that C.W.'s environment did not support continued use of skills learned in therapy. C.W.'s internal motivation to sustain improvement was not high.

Subject R.B.

A stable pretreatment baseline was obtained ($C = 0.09$, $Z = 0.29$, $p > 0.05$), and the average percent correct was 68.75 for the baseline (**Table 1**). During phase 3, his average score improved to 95.63 percent correct (**Table 1**). The slopes of the total percent of correctly named pictures from the treatment phases demonstrated a significant upward trend from baseline measures ($C = 0.89$, $Z = 5.50$, $p < 0.05$) (**Figure 4(a)**). Again, naming accuracy improved for both the trained and untrained pictures, with no noticeable difference in performance between trained and untrained pictures (**Figure 4(b)**).

R.B.'s use of the gesture was limited to the treatment sets, and he did not use the gesture while naming pictures in the probe set. A follow-up naming probe, similar to the one administered during treatment of J.S. and C.W., was administered 6 months after completion of the study. R.B. accurately named 85.00 percent of the pictures. However, this set of pictures was not exclusively composed of low frequency words, as in his original probe, so this score may be an overestimate of his true naming ability. Apparently, the gains demonstrated in treatment either were not fully maintained or generalized to the follow-up probe set, because his naming accuracy score decreased from the percentages correct he had obtained by the end of treatment.

Subjects did not demonstrate consistent improvements across treatment on the copy of the Rey-Osterrieth Complex Figure Test or on the Wechsler Adult Intelligence Scale—Revised Edition, Block Design subtest,

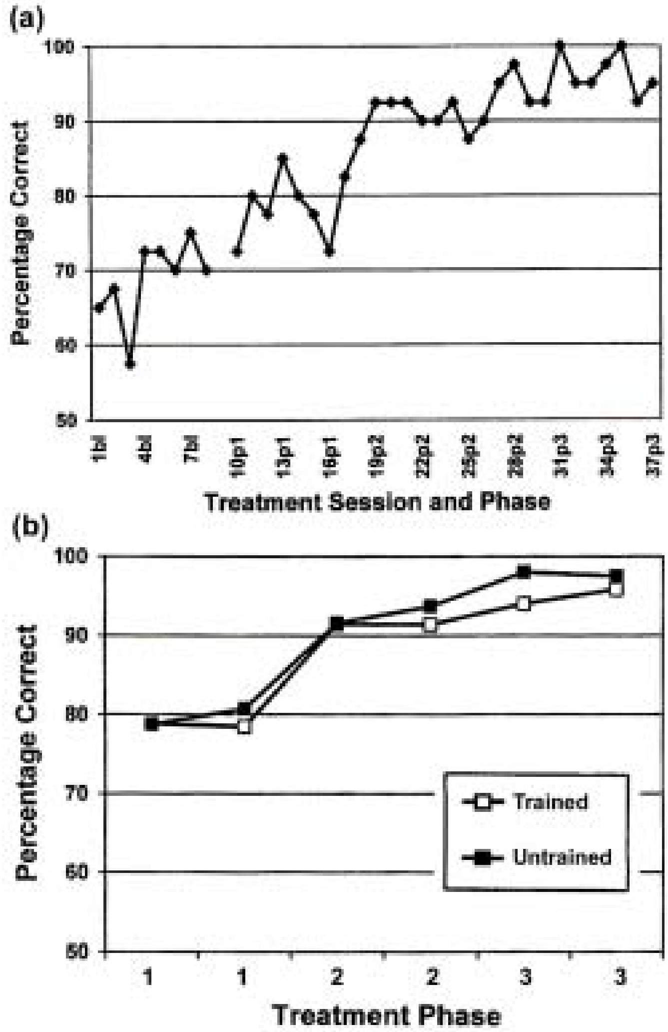

Figure 4.
Subject R.B.: **(a)** Percent correct for all probe trials in baseline and treatment sessions. First nine sessions were baseline sessions, followed by 10 phase 1 treatment sessions, 10 phase 2 treatment sessions, and 9 phase 3 treatment sessions. (Data were lost for one baseline session.) bl = baseline, p1 = phase 1, p2 =phase 2, p3 = phase 3. **(b)** Percent correct for trained and untrained items in probe set. Percent correct was averaged across first and second halves of each treatment phase.

that were measured before each phase and at treatment completion (**Table 2**). This finding suggests that the treatment was specific to language initiation, and improvements demonstrated were not merely a result of general cognitive improvement. Scores on Block Design ranged from 26 to 34 for J.S., 26 to 31 for C.W., and 49 to 51 for R.B. On the Rey-Osterrieth Complex Figure Test, scores for copy ranged from 32 to 34 for J.S., 27 to 30 for C.W., and 28 to 35 for R.B.

DISCUSSION

The results of this study demonstrated that nonfluent aphasic patients can improve their picture-naming ability by performing a complex action with the nondominant hand while naming. All three subjects demonstrated a significant improvement in their naming accuracy, as measured by an increase in percentage correct on the verbal naming probes administered during treatment. While all three subjects demonstrated an improvement, they did so differentially. For example, J.S. improved more on trained than untrained stimuli, while R.B. improved on both types of stimuli. Such differences are important because if they are consistent between a majority of subjects, they could affect how this new treatment is applied to obtain optimal results. Specifically, if patients improve primarily on trained stimuli, then treatment should focus on training those words they most need to function in their daily environment. Possible mechanisms behind intersubject differences, such as severity of aphasia or ability to repeat, will be the focus of future studies that will be run in an experimental treatment versus control treatment design.

The improvements demonstrated in the current study are consistent with the concept that activation of right-hemisphere intentional mechanisms can be accomplished through nonsymbolic movements of the left hand and that the priming of these intentional mechanisms facilitates naming. However, definitive support for this hypothesis awaits further research in which the active component of the treatment is experimentally isolated. In addition, this study showed that subjects could improve their naming accuracy for pictures that were never paired with the movement sequence in addition to pictures that were paired with the sequence, suggesting that the engagement of intentional mechanisms was not item specific but more broadly facilitated naming and language initiation. Finally, subjects did not consistently improve on tasks that measured visuospatial processing and constructional abilities, suggesting that the treatment was language specific and not because of a generalized cognitive improvement.

We chose an A-B single subject design for this pilot study to assess whether the newly developed treatment of intentional deficits in aphasia showed enough promise to merit further investment of significant resources in a more elaborate and definitive study. All subjects in this study demonstrated statistically significant improvement

Table 2.
Raw scores for Block Design and Rey-Osterrieth, completed before initiation of each phase.

	J.S.		C.W.		R.B.	
Phase	**Block Design**	**Rey-Osterrieth**	**Block Design**	**Rey-Osterrieth**	**Block Design**	**Rey-Osterrieth**
Baseline	26	Not administered	26	28.0	49	28
1	26	34	31	27.5	47	35
2	26	32	26	27.0	51	35
3	34	34	31	30.0	53	32

over baseline performance. These promising results from the initial subjects indicate that the treatment deserves further attention in a more elaborate study that includes comparison to an alternate (i.e., control) treatment.

Limitations of this pilot study should be discussed because they influence both the interpretation and generalizability of the findings. The most important limitation in an A-B design is that it does not entirely rule out the possibility that factors other than the treatment could have influenced the subject's performance. For example, repeated exposure to the same probe set across the entire treatment eventually could have led to improved performance, despite the stable baseline. Findings from a previous study with symbolic gestures indicated that training requiring repeated naming of pictures did not lead to improvement in naming probes and suggested that mere exposure to stimuli over time may not account for improvement [6]. A second limitation is that the improvement of a single subject does not imply that positive findings will occur during treatment of other subjects. In this study, one subject (R.B.) received different treatment and probe sets than the others (J.S. and C.W). Improvements were demonstrated in all subjects, despite their exposure to different stimuli, which suggests that the increases were not merely a product of the stimulus and probe sets employed. In addition, the language symptoms of our subjects were quite variable, and therefore it was encouraging that this new treatment may be appropriate for a variety of nonfluent aphasia patients.

The theory motivating this study suggests that improvements demonstrated are due to a functional shift of language initiation mechanisms to right-hemisphere medial frontal cortex. In patients with chronic nonfluent aphasia following stroke, language production areas shift from left lateral frontal cortex to a homologous region in the right hemisphere while left medial frontal areas remain active [3]. We suggest that more chronic aphasics with large lesions, similar to those in this study, may demonstrate a better recovery with unilateral, right-hemisphere language initiation and production, as opposed to when initiation and production mechanisms are in different hemispheres.

In summary, results from this pilot study offer promising data regarding the use of nonsymbolic movement sequences in rehabilitation of nonfluent aphasia. Additional research must be conducted to determine the active component in this experimental treatment and its underlying neural mechanisms. Ways of making treatment gains more permanent for some patients also should be investigated.

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